

Claims

[c1] 1. An apparatus for protecting optical fiber in an optical fiber hydrophone module as the fiber transitions between components of the module, the module comprising a fiber transition segment, a module oil seal assembly, and a hydrophone assembly adjacent to the fiber transition segment, the module having a central axis and an outermost hose surrounding an internal strength member that surrounds the other components of the module with two affixed positioning tapes substantially parallel to the central axis, the hydrophone assembly comprising a plurality of mandrels helically wrapped with optical fiber and connected in linear relation with interconnect springs having a helical groove that receives the optical fiber, the fiber transition segment comprising a conical, elongated element having first and second ends, the first end adapted to be connected to the hydrophone assembly, and having a helical groove for receiving the optical fiber from the assembly so that the fiber transitions to the central axis of the module, the fiber protecting apparatus comprising:

an elastic woven fiber strap having a first side, a second side, a first layer, a second layer, a first end, a longitudinal middle portion, and a second end, wherein the strap at the first end and longitudinal middle portion are substantially aligned with the central axis of the hydrophone module, the first layer and second layer are fastened together in the longitudinal middle portion, the first end of the strap comprises a loop, and the first and second layers at the second end of the strap are spatially separated and extend at least in part on opposite sides of the fiber transition segment; and

a first tube in which an optical fiber is disposed, the first tube attached to the strap in a sinusoidal pattern to at least the longitudinal middle portion of the first layer of the strap;

wherein the first end of the strap is adapted to be attached to a relatively fixed element and the first and second layers at the second end of the strap are adapted to be attached to a relatively movable element, and wherein elongation of the strap causes the period of the sinusoidal pattern to increase without imparting damaging stress to the optical fiber.

- [c2] 2.A fiber protecting apparatus as recited in claim 1, wherein the first tube is attached to at least the longitudinal middle portion of the first side of the strap.
- [c3] 3.A fiber protecting apparatus as recited in claim 1, wherein the elongation of the strap is at least 50 percent.
- [c4] 4.A fiber protecting apparatus as recited in claim 2, wherein the elastic woven fiber strap has a fiber made of thermoplastic multi-filament yarn spun from liquid crystal polymer woven into the strap along the borders of the strap.
- [c5] 5.A fiber protecting apparatus as recited in claim 1, wherein the first tube is made of PTFE.
- [c6] 6.A fiber protecting apparatus as recited in claim 1, further comprising a second tube attached to at least the longitudinal middle portion of the second layer of the strap in a sinusoidal pattern, the second tube receiving at least one optical fiber.

- [c7] 7.A fiber protecting apparatus as recited in claim 1, wherein the second tube is attached to at least the longitudinal middle portion of the second side of the strap.
- [c8] 8.A fiber protecting apparatus as recited in claim 5, wherein the second tube is made of poly-paraphenylene terephthalamide.
- [c9] 9.A fiber protecting apparatus as recited in claim 1, wherein the strap comprises one length of strap material that is folded at its longitudinal midpoint to make the first end, second end, first layer, and second layer, and having the looped first end at the location of the fold, and further comprising a third central layer in the longitudinal middle portion disposed between the first and second layers.
- [c10] 10.A fiber protecting apparatus as recited in claim 7, wherein the loop at the folded first end of the strap is adapted to be fastened to a module oil seal assembly.
- [c11] 11.A fiber protecting apparatus as recited in claim 1, wherein the branches at the spatially separated end of the strap extend alongside the fiber transition segment and are fastened to the respective positioning tapes of the internal strength member.
- [c12] 12.A fiber protecting apparatus as recited in claim 7, wherein the first tube is attached in the longitudinal middle portion of the strap between the first and third layers.
- [c13] 13.A fiber protecting apparatus as recited in claim 7, further comprising a

second tube attached to the strap in a sinusoidal pattern, the second tube receiving at least one optical fiber and being attached in the longitudinal middle portion of the strap between the second and third layers.

[c14] 14. An apparatus for protecting the optical fiber for use in an optical fiber hydrophone module as the fiber transitions between components of the module, the module comprising a fiber transition segment, a module oil seal assembly, and a hydrophone assembly adjacent to the fiber transition segment, the module having a central axis and an outermost hose surrounding an internal strength member that surrounds the other components of the module with two affixed positioning tapes substantially parallel to the central axis, the hydrophone assembly comprising a plurality of mandrels helically wrapped with optical fiber and connected in linear relation with interconnect springs having a helical groove that receives the optical fiber, the fiber transition segment comprising a conical, elongated element having first and second ends, the first end adapted to be connected to the hydrophone assembly, and having a helical groove for receiving the optical fiber from the assembly so that the fiber transitions to the central axis of the module, the fiber protecting apparatus comprising:

an elastic woven fiber strap; and

a tube in which an optical fiber is disposed, the tube attached to the strap in a sinusoidal pattern and having a coiled end not attached to the strap, the coiled end of the tube wrapped around the fiber transition segment and receiving the optical fiber as the fiber transitions from the fiber transition segment to the central axis of the module.

[c15] 15..An optical fiber hydrophone module for protecting optical fiber as the fiber transitions between components of the module, the module having a longitudinal central axis and comprising:

a fiber transition segment, the fiber transition segment comprising a conical, elongated element having first and second ends, the first end adapted to be connected to the hydrophone assembly, and having a helical groove for receiving the optical fiber from the assembly so that the fiber transitions to the central axis of the module;

a module oil seal assembly;

a hydrophone assembly adjacent to the fiber transition segment, the hydrophone assembly comprising a plurality of mandrels helically wrapped with optical fiber and connected in linear relation with interconnect springs having a helical groove that receives the optical fiber;

an elastic woven fiber strap having a first side, a second side, a first layer, a second layer, a first end, a longitudinal middle portion, and a second end, wherein the strap at the first end and longitudinal middle portion are substantially aligned with the central axis of the hydrophone module, the first layer and second layer are fastened together in the longitudinal middle portion, the first end of the strap comprises a loop, and the first and second layers at the second end of the strap are spatially separated and extend at least in part on opposite sides of the fiber transition segment;

a first tube in which an optical fiber is disposed, the first tube attached to the strap in a sinusoidal pattern to at least the longitudinal middle portion of the first layer of the strap; and

an internal strength member surrounding the fiber transition segment, module oil seal assembly, hydrophone assembly, and woven fiber strap, and first tube, with two affixed positioning tapes substantially parallel to the central axis,

wherein the first end of the strap is attached to the module oil seal assembly and the first and second layers at the second end of the strap are attached to respective positioning tapes, and wherein elongation of the strap causes the period of the sinusoidal pattern to increase without imparting damaging stress to the optical fiber.

- [c16] 16. A fiber protecting apparatus as recited in claim 15, further comprising a second tube attached to at least the longitudinal middle portion of the second layer of the strap in a sinusoidal pattern, the second tube receiving at least one optical fiber.
- [c17] 17. A method for protecting an optical fiber as the fiber transitions between components of an optical fiber hydrophone module, the module comprising a fiber transition segment, a module oil seal assembly, and a hydrophone assembly adjacent to the fiber transition segment, the module having a central axis and an outermost hose surrounding an internal strength member that surrounds the other components of the module with two affixed positioning tapes substantially parallel to the central axis, the hydrophone assembly comprising a plurality of mandrels helically wrapped with optical fiber and connected in linear relation with interconnect springs having a helical groove that receives the optical fiber, the fiber transition segment comprising a conical, elongated element having first and second ends, the first end adapted to be

connected to the hydrophone assembly, and having a helical groove for receiving the optical fiber from the assembly so that the fiber transitions to the central axis of the module, the fiber protecting steps comprising:
providing an elastic woven fiber strap having a first side, a second side, a first layer, a second layer, a first end, a longitudinal middle portion, and a second end, wherein the strap at the first end and longitudinal middle portion are substantially aligned with the central axis of the hydrophone module, the first layer and second layer are fastened together in the longitudinal middle portion, the first end of the strap comprises a loop, and the first and second layers at the second end of the strap are spatially separated and extend at least in part on opposite sides of the fiber transition segment; and
attaching a first tube in which an optical fiber is disposed to the strap in a sinusoidal pattern to at least the longitudinal middle portion of the first layer of the strap,
wherein elongation of the strap causes the period of the sinusoidal pattern to increase without imparting damaging stress to the optical fiber.

- [c18] 18.A method for protecting an optical fiber further comprising the steps of:
attaching the first end to a relatively fixed element; and
attaching the first and second layers at the second end of the strap to a relatively movable element.
- [c19] 19.A method for protecting an optical fiber as the fiber transitions between components of an optical fiber hydrophone module, the module comprising a fiber transition segment, a module oil seal assembly, and a

hydrophone assembly adjacent to the fiber transition segment, the module having a central axis and an outermost hose surrounding an internal strength member that surrounds the other components of the module with two affixed positioning tapes substantially parallel to the central axis, the hydrophone assembly comprising a plurality of mandrels helically wrapped with optical fiber and connected in linear relation with interconnect springs having a helical groove that receives the optical fiber, the fiber transition segment comprising a conical, elongated element having first and second ends, the first end adapted to be connected to the hydrophone assembly, and having a helical groove for receiving the optical fiber from the assembly so that the fiber transitions to the central axis of the module, the fiber protecting steps comprising: providing an elastic woven fiber strap; attaching a tube for holding an optical fiber to the strap in a sinusoidal pattern; coiling an end of the tube not attached to the strap; wrapping the coiled end of the tube around the fiber transition segment; and receiving the optical fiber as the fiber transitions from the fiber transition segment to the central axis of the module.